Amendments to the Specification

Please substitute the following paragraph for paragraph [0036]:

Energy source 12 may be a gas turbine, photovoltaics, wind turbine or any other conventional or newly developed source. Energy storage device 20 may be a flywheel, battery, ultracap or any other conventional or newly developed energy storage device. Load 18 may be ~~an~~ a utility grid, dc load, drive motor or any other conventional or newly developed utility/load 18.

Please substitute the following paragraph for paragraph [0038]:

In accordance with the present invention, each power converter 14, 16 and 22 operates essentially as a customized, bi-directional switching converter under the control of main CPU 32, which uses SP 30 to perform its operations. Main CPU 32 provides both local control and sufficient intelligence to form a distributed processing system. Each power converter 14, 16 and 22 is tailored to provide an interface for a specific energy component to DC bus 24. Main CPU 32 controls the way in which each energy component 12, 18 and 20 sinks or sources power, and DC bus 24 is regulated at any time. In particular, main CPU 32 reconfigures the power converters 14, 16 and 22 into different configurations for different modes of operation. In this way, various energy components 12, 18 and 20 can be used to supply, store and/or use power in an efficient manner. In the case of a turbine power generator, for example, a conventional system regulates turbine speed to control the output or bus voltage. In the power controller, the

bi-directional controller ~~independently of turbine speed~~ regulates the bus voltage independently of turbine speed.

Please substitute the following paragraph for paragraph [0041]:

Referring to FIG. 3, a simplified block diagram of a turbine system 50 using the power controller electronics architecture of the present invention is illustrated. The turbine system 50 includes a fuel metering system 42, turbine engine 58, power controller 52, energy reservoir conversion 62, energy/reservoir 64 and load/utility grid 60. The fuel metering system 42 is matched to the available fuel and pressure. The power controller 52 converts the electricity from turbine engine 58 into regulated DC and then ~~converts it to~~ into utility grade AC electricity. By separating the engine control from the converter that creates the utility grade power, greater control of both processes is realized. All of the interconnections are comprised of a communications bus and a power connection.

Please substitute the following paragraph for paragraph [0043]:

Referring to FIG. 4, the power architecture 68 of a typical implementation of ~~the~~ a power controller 70 is shown. The power controller 70 includes a generator converter 72 and output converter 74 which provides for the two power conversions that take place between the turbine 76 and the load/utility grid 78. In particular, the generator converter 72 provides for AC to DC power conversion and the output converter 74 provides for DC to AC power conversion. Both of these power converters 72 and 74 are capable of

operating in a forward or reverse direction. This allows starting the turbine 76 from either the energy storage device 86 or the load/utility grid 78. Since the energy may flow in either direction to or from the energy storage device 86, transients may be handled by supplying energy or absorbing energy. The energy storage device 86 and its DC converter 84 are not contained inside the power controller 70. The DC converter 84 provides for DC to DC power conversion.

Please substitute the following paragraph for paragraph [0044]:

Referring to FIG. 5, a schematic 90 of a typical internal power architecture, such as that shown in FIG. 4, is shown. The turbine has an integral PMG that can be used as either a ~~generator~~ motor (for starting) or a generator (normal mode of operation). Because all of the controls can be performed in the digital domain and all switching (except for one output contactor) is done with solid state switches, it is easy to shift the direction of the power flow as needed. This permits very tight control of the turbine during starting and stopping. In a typical configuration, the power output is a 480 VAC, 3-phase output. One skilled in the art will recognize that the present invention may be adapted to provide for other power output requirements such as a 3-phase, 400 VAC, and single-phase, 480 VAC.

Please substitute the following paragraph for paragraph [0046]:

IGBT module 94 is part of the electronics that controls the engine of the turbine. IGBT module 94 incorporates gate driver and fault sensing circuitry as well as a seventh

IGBT used to dump power into a resistor. The gate drive inputs and fault outputs require external isolation. Four external, isolated power supplies are required to power the internal gate drivers. IGBT module 94 is typically used in a turbine system that generates 480 VAC at its output terminals delivering up to 30 kwatts to a freestanding or utility-connected load. During startup and cool down (and occasionally during normal operation), the direction of power flow through the seven-pack reverses. When the turbine is being started, power is supplied to the DC bus 112 from either a battery (not shown) or from the utility grid 108. The DC is converted to a variable frequency AC voltage to ~~generator~~ motor the turbine.

Please substitute the following paragraph for paragraph [0049]:

Six-pack IGBT module 96 is part of the electronics that controls the converter of the turbine. IGBT module 96 incorporates gate driver and fault sensing circuitry. The gate drive inputs and fault outputs require external isolation. Four external, isolated power supplies are required to power the internal gate drivers. IGBT module 96 is typically used in a turbine system that generates 480 VAC at its output terminals delivering up to approximately 30 kwatts to a free-standing or utility-connected load. After the turbine is running, six-pack IGBT module 96 is used to convert the regulated DC bus voltage to the approximately 50 or 60 hertz utility grade power. When there is no battery (or other energy reservoir), the energy to run the engine during startup and cool down must come from utility grid 108. Under this condition, the direction of power flow through the six-pack IGBT module 96 reverses. DC bus 112 receives its energy from utility grid 108, using six-pack IGBT module 96 as a boost converter (the power diodes

act as a rectifier). The DC is converted to a variable frequency AC voltage to ~~generator~~ motor the turbine. To accelerate the engine as rapidly as possible at first, current flows at the maximum rate through seven-pack IGBT module 94 and also six-pack IGBT module 96.

Please substitute the following paragraph for paragraph [0051]:

Energy is needed to start the turbine. Referring to FIGS. 3 and 4, this energy may come from utility grid 60 or from energy reservoir 64, such as a battery, flywheel or ultra-cap. When utility grid 60 supplies the energy, utility grid 60 is connected to power controller 52 through two circuits. First is an output contactor that handles the full power (30 kwatts). Second is a "soft-start" or "pre-charge" circuit that supplies limited power (it is current limited to prevent very large surge currents) from utility grid 60 ~~66~~ to DC bus 66 ~~62~~ through a simple rectifier. The amount of power supplied through the soft-start circuit is enough to start the housekeeping power supply, power the control board, and run the power supplies for the IGBTs, and close the output contactor. When the contactor closes, the IGBTs are configured to create DC from the AC waveform. Enough power is created to run the fuel metering circuit 42, start the engine, and close the various solenoids (including the dump valve on the engine).

Please substitute the following paragraph for paragraph [0052]:

[0052] When energy reservoir 64 supplies the energy, energy reservoir 64 has its own power conversion circuit 62 that limits the surge current ~~circuit~~ into DC bus

capacitors. Energy reservoir 64 allows enough power to flow to DC bus 66 ~~62~~ to run fuel-metering circuit 42, start the engine, and close the various solenoids (including the dump valve on the engine). After the engine becomes self-sustaining, the energy reservoir starts to replace the energy used to start the engine, by drawing power from DC bus 66 ~~62~~. In addition to the sequences described above, power controller 52 senses the presence of other controllers during the initial power up phase. If another controller is detected, the controller must be part of a multi-pack, and proceeds to automatically configure itself for operation as part of a multi-pack.

Please substitute the following paragraph for paragraph [0053]:

Referring to FIG. 6, a functional block diagram 130 of an interface between utility grid 132 and turbine generator 148 using power controller 136 of the present invention is shown. In this example, power controller 136 includes two bi-directional converters 138 and 140. Permanent magnet generator converter 140 starts turbine 148 (using the generator as a ~~generator~~ motor) from utility or battery power. Load converter 138 then produces AC power using an output from generator converter 140 to draw power from high-speed turbine generator 148. Power controller 136 also regulates fuel to turbine 148 and provides communications between units (in paralleled systems) and to external entities.

Please substitute the following paragraph for paragraph [0054]:

During a utility startup sequence, utility 132 supplies starting power to turbine 148 by "actively" rectifying the line via load converter 138, and then converting the DC to variable voltage, variable frequency 3-phase power in generator converter ~~136~~ <u>140</u>. As is illustrated in FIG. 7, for stand-alone applications 150, the start sequence is the same as the utility start sequence shown in FIG. 6 with the exception that the start power comes from battery 170 under the control of an external battery controller. Load 152 is then fed from the output terminals of load converter 158.

Please substitute the following paragraph for paragraph [0057]:

Solid state (IGBT) switches <u>212</u> ~~214~~ associated with generator converter 186 are also driven from control logic 184, providing a variable voltage, variable frequency 3-phase drive to generator ~~218~~ <u>208</u> to start turbine ~~208~~ <u>206</u>. Control logic 184 receives feedback via current sensors Isens as turbine 206 is ramped up in speed to complete the start sequence. When turbine 206 achieves a self sustaining speed of, for example, approx. 40,000 RPM, generator converter 186 changes its mode of operation to boost the generator output voltage and provide a regulated DC bus voltage.

Please substitute the following paragraph for paragraph [0063]:

[0063] Commanded operating modes are used to determine how power is switched through the major converts in the controller. The software is responsible for

turbine engine control and issuing commands to other SP processors enabling them to perform the generator converter and output converter power switching. The controls also interface with externally connected energy storage devices (not shown) that provide black start and transient capabilities.

Please substitute the following TABLE 1 for TABLE 1 on page 36 of the present application:

TABLE 1

~~B3~~ POWER OUTPUT	SETPOINT
480/400 VAC Output	800 Vdc
240/208 VAC Output	400 Vdc

Please substitute the following TABLE 2 for TABLE on pages 37-38 of the present application:

TABLE 2

STATE #	SYSTEM STATE	DESCRIPTION
0	Power Up	Performs activities of initializing and testing the system.
1	Stand By	~~Closer~~ Connects power to bus and continues system monitoring while waiting for a start command.
2	Prepare to start	Initializes any external devices preparing for the start procedure.
3	Bearing	Configures the system and commands the

	Lift Off	engine to be rotated to a predetermined RPM, such as 25,000 RPM.
4	Open Loop Light Off	Turns on ignition system and commands fuel open loop to light the engine.
5	Closed Loop Acceleration	Continues motoring and closed fuel control until the system reaches the no load state.
6	Run	Engine operates in a no load self-sustaining state producing power only to operate the controller.
7	Load	Converter output contactor is closed and system is producing power.
8	Re-Charge	System operates off of fuel only and produces power for recharging energy storage device if installed.
9	Cooldown	System is motoring engine to reduce EGT before shutting down.
10	Re-Start	Reduces engine speed to begin open loop light when a start command is received in the cooldown state.
11	Re-Light	Performs a turbine re-light in transition from the cooldown to warmdown state. Allows continued engine cooling when motoring is no longer possible.
12	Warmdown	Sustains turbine operation with fuel at a predetermined RPM, such as 50,000 RPM, to cool when engine motoring is not possible.
13	Shutdown	Reconfigures the system after a cooldown to enter the stand by state.
14	Fault	Turns off all outputs when presence of fault which disables power conversion exists. Logic power is still available for interrogating system faults.
15	Disable	Fault has occurred where processing may no longer be possible. All system operation is disabled.

Please substitute the following paragraph for paragraph [0093]:

[0093] Main CPU 472 begins execution in the "power up" state 322 after power is applied. Transition to the "stand by" state 324 is performed upon successfully completing the tasks of the "power up" state 322. Initiating a start cycle transitions the system to the "prepare to start" state 326 where all system components are initialized for an engine start. The engine then sequences through start states and onto the "run/load" state 328. To shutdown the system, a stop command which sends the system into either "warm down" or "cool down" state 332 is initiated. Systems that have a battery may enter the "re-charge" state 334 prior to entering the "warm down" or "cool down" state 332. When the system has finally completed the "warm down" or "cool down" process 332, a transition through the "shut down" state 330 will be made before the system re-enters the "standby" state 324 awaiting the next start cycle. During any state, detection of a fault with a system severity level indicating the system should not be operated will transition the system state to "fault" state <u>335</u> ~~334~~. Detection of faults that indicate a processor failure has occurred will transition the system to the "disable" state 336.

Please substitute the following paragraph for paragraph [0095]:

Separate "power up" 322, "re-light" 338, "warm down" <u>348</u> ~~332~~, "fault" <u>335</u> ~~334~~ and "disable" 336 states are not required for each mode of operation. The contents of these states are mode independent.

Please substitute the following paragraph for paragraph [0097]:

Main CPU 472 continues to perform normal system monitoring in the "stand by" state 324 while it waits for a start command signal. Main CPU 472 commands either energy storage device 470 or utility 468 to provide continuous power supply. In operation, main CPU 472 will often be left powered on waiting to be ~~start~~ started or for troubleshooting purposes. While main CPU 472 is powered up, the software continues to monitor the system and perform diagnostics in case any failures should occur. All communications will continue to operate providing interface to external sources. A start command will transition the system to the "prepare to start" state 326.

Please substitute the following paragraph for paragraph [0114]:

Referring to FIG. 14, generator converter 456 and load converter 458 provide an interface for energy source 460 and utility 468, respectively, to DC bus 462. For illustrative purposes, energy source 460 is a turbine including engine 454 and generator 452. Fuel device 474 provides fuel via fuel line 476 to engine 454. Generator converter 456 and load converter 458 operate as customized bi-directional switching converters under the control of controller 472. In particular, controller 472 reconfigures the generator converter 456 and load converter 458 into different configurations to provide for the various modes of operation. These modes include stand-alone black start, stand-alone transient, utility grid connect and utility grid connect transient as discussed in detail below. Controller 472 controls the way in which generator 452 and utility 468 sinks or sources power, and DC bus 462 is regulated at any time. In this way, energy

source 460, utility/load 468 and energy storage device 470 can be used to supply, store and/or use power in an efficient manner. Controller 472 provides command signals via line 479 to engine 454 to determine the speed of turbine 460. The speed of turbine 460 is maintained through generator 452. Controller 472 also provides command signals via control line 480 to fuel device 474 to maintain the EGT of the engine 454 at its maximum efficiency point. Generator SP 456 is responsible for maintaining the speed of the turbine 460, ~~but~~ by putting current into generator 452 or pulling current out of generator 452.

Please substitute the following paragraph for paragraph [0116]:

In the stand-alone transient mode, storage device 470 ~~479~~ is provided for the purpose of starting and assisting the energy source 460, in this example the turbine, to supply maximum rated output power during transient conditions. Storage device 470 ~~479~~, typically a battery, is always attached to DC bus 462 during operation, supplying energy in the form of current to maintain the voltage on DC bus 462. Converter/SP 458 provides a constant voltage source when producing output power. As a result, load 468 is always supplied the proper AC voltage value that it requires. Referring to TABLE 4, controls for a typical stand-alone transient mode are shown.

Please substitute the following paragraph for paragraph [0133]:

In a typical configuration, AC ~~motor~~ generator 618 produces three phases of AC at variable frequencies. AC/DC converter 602 under the control of ~~motor~~ generator SP

606 converts the AC to DC which is then applied to DC bus 622 (regulated for example at 800 vDC) which is supported by capacitor 610 (for example, at 800 microfarads with two milliseconds of energy storage). AC/DC converter 604, under the control of converter SP 608, converts the DC into three-phase AC, and applies it to utility grid 616. In accordance with the present invention, current from DC bus 622 can by dissipated in brake resistor 612 via modulation of switch 614 operating under the control of ~~motor~~ generator SP 606. Switch 614 may be an IGBT switch, although one skilled in the art will recognize that other conventional or newly developed switches may be utilized as well.

Please substitute the following paragraph for paragraph [0134]:

~~Motor~~ Generator SP 606 controls switch 614 in accordance to the magnitude of the voltage on DC bus 622. The bus voltage of DC bus 622 is typically maintained by converter SP 608, which shuttles power in and out of utility grid 616 to keep DC bus 622 regulated at, for example, 800 vDC. When converter SP 608 is turned off, it no longer is able to maintain the voltage of DC bus 622, so power coming in from the ~~motor~~ generator causes bus voltage of DC bus 622 to rise quickly. The rise in voltage is detected by ~~motor~~ generator SP 606, which turns on brake resistor 612 and modulates it on and off until the bus voltage is restored to its desired voltage, for example, 800 vDC. Converter SP 608 detects when the utility grid transient has dissipated, i.e., AC current has decayed to zero and restarts the converter side of power controller 620. Brake resistor 612 is sized so that it can ride through the transient and the time taken to restart converter 604.

Please substitute the following paragraph for paragraph [0135]:

[0154] Referring to FIGS. 16 and 18 ~~18 and 20~~, in accordance with the present invention, both the voltage and zero crossings (to determine where the AC waveform of utility grid 616 crosses zero) are monitored to provide an accurate model of utility grid 616. Utility grid analysis system includes angle estimator 582, magnitude estimator 584 and phase locked loop 586. The present invention continuously monitors utility grid voltage and based on these measurements, estimates the utility grid angle, thus facilitating recognition of under/over voltages and sudden transients. Current limits are set to disable DC/AC converter 604 when current exceeds a maximum and wait until current decays to an acceptable level. The result of measuring the current and cutting it off is to allow DC/AC converter 604 to ride through transients better. Thus when DC/AC converter 608 is no longer exchanging power with utility grid 616, power is dissipated in brake resistor 612.

Please substitute the following paragraph for paragraph [0136]:

In accordance with the present invention, converter SP 608 is capable of monitoring the voltage and current at utility grid 616 simultaneously. In particular, power controller 620 includes a utility grid analysis algorithm. One skilled in the art will recognize that estimates of the utility grid angle and magnitude may be derived via conventional algorithms or means. The true utility grid angle θAC ~~θAC~~, which is the angle of the generating source, cycles through from 0 to ~~2θ~~ 2π and back to 0 at a rate of 60 hertz. The voltage magnitude estimates of the three phases are designated V1 mag,

V2 mag and V3 mag and the voltage measurement of the three phases are designated V1, V2 and V3.

Please substitute the following paragraph for paragraph [0137]:

A waveform, constructed based upon the estimates of the magnitude and angle for each phase, indicates what a correct measurement would look like. For example, using the first of the three phase voltages, the cosine of the true utility grid angle θAC ~~θAC~~ is multiplied by the voltage magnitude estimate V1 mag, with the product being a cosine-like waveform. Ideally, the product would be equal to the voltage measurement V1.

Please substitute the following paragraph for paragraph [0138]:

Feedback loop 588 uses the difference between the absolute magnitude of the measurement of V1 and of the constructed waveform to ~~adjusts~~ adjust the magnitude of the magnitude estimate V1 mag. One skilled in the art will recognize that the other two phases of the three-phase signal can be adjusted similarly, with different angle templates corresponding to different phases of the signal. Thus, magnitude estimate V1 mag and angle estimate θEST ~~θEST~~ are used to update magnitude estimate V1 mag. Voltage magnitude estimates V1 mag, V2 mag and V3 mag are steady state values used in a feedback configuration to track the magnitude of voltage measurements V1, V2 and V3. By dividing the measured voltages V1 by the estimates of the magnitude V1 mag, the

cosine of the angle for the first phase can be determined (similarly, the cosine of the angles of the other signals will be similarly determined).

Please substitute the following paragraph for paragraph [0139]:

In accordance with the present invention, the most advantageous estimate for the cosine of the angle, generally the one that is changing the most rapidly, is chosen to determine the instantaneous measured angle. In most cases, the phase that has an estimate for the cosine of an angle closest to zero is selected since it yields the greatest accuracy. Utility grid analysis system 580 thus includes logic to select which one of the cosines to use. The angle chosen is applied to angle estimator 582, from which an estimate of the instantaneous angle ~~θEST~~ of utility grid 616 is calculated and applied to phase locked loop 586 to produce a filtered frequency. The angle is thus differentiated to form a frequency that is then passed through a low pass filter (not shown). Phase locked loop 586 integrates the frequency and also locks the phase of the estimated instantaneous angle <u>θEST</u> ~~θEST~~, which may have changed in phase due to differentiation and integration, to the phase of true utility grid angle <u>θAC</u> ~~θAC~~.

Amendments to the Drawings

Please substitute the attached FIG. 13 Replacement Sheet for pending FIG. 13.

Please substitute the attached FIG. 19 Replacement Sheet for pending FIG. 19.

Please substitute the attached FIG. 20 Replacement Sheet for pending FIG. 20.

Please substitute the attached FIG. 21 Replacement Sheet for pending FIG. 21.